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**Electromagnetic detection system.**

An electromagnetic detection system comprising at least one source circuit and at least one source circuit-controlled antenna configuration, which comprises two loop antenna coils, substantially located in one plane or in closely spaced parallel planes, for generating a detection field in a detection zone, and a plurality of responders, provided with a loop antenna coil, detectable in the detection zone by means of the detection field, wherein one loop antenna coil of the antenna configuration is part of a series resonance circuit, and that the other loop antenna coil is part of a parallel resonance circuit, the series and parallel resonance circuits having the same resonance frequency and being interconnected to form a combined antenna network connected to the source circuit, and the series and parallel resonance circuits being dimensioned such that the frequency-dependent parts of the impedances substantially compensate each other, so that the combined antenna network has a substantially frequency-independent impedance.

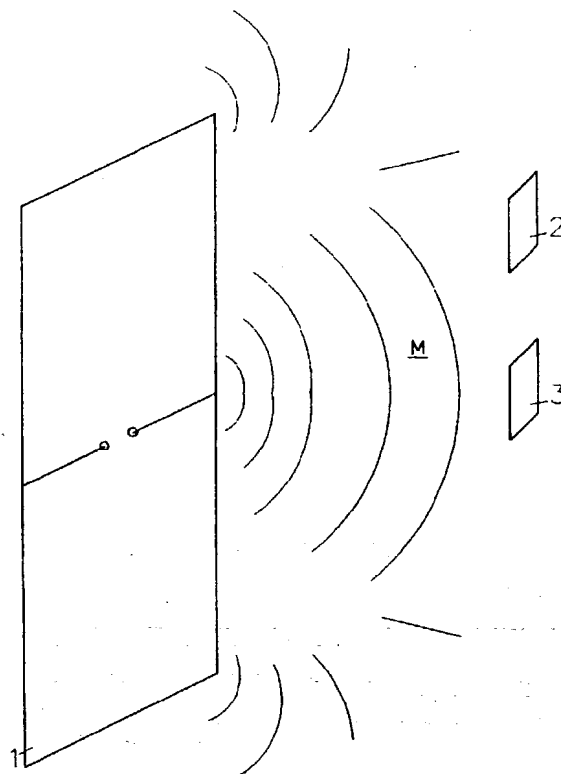


FIG.1

The invention relates to an electromagnetic detection system comprising at least one source circuit and at least one source circuit-controlled antenna configuration, which comprises two loop antenna coils, substantially located in one plane or in closely spaced parallel planes, for generating a detection field in a detection zone, and a plurality of responders, provided with a loop antenna coil, detectable in the detection zone by means of the detection field.

Presently, eight-shaped antennas are typically used in RF-systems for shoplifting detection. Eight-shaped antennas have the advantage that the field strength at a short distance (up to approximately half the height) is relatively strong compared to the field strength at a large distance, the antenna thus being less susceptible to interference from outside the system than, for instance, zero-shaped antennas. The drawback of eight-shaped antennas is that at half-level, the field lines are vertically oriented. At this level, a vertically oriented label does not cross any field lines and is therefore not detected, unlike a label at a different level.

However, the position of a label, attached to an article which is carried in a trouser pocket (ca. half-level) is usually vertical; consequently, the label is not detected. The phenomenon that at trouser pocket level the label can pass the passageway without being detected is commonly referred to as the trouser pocket effect. This effect does not occur in the case of an antenna configuration that generates a rotary field. Such an antenna configuration is for instance disclosed in EP-A-0186483. The known antenna configuration comprises two loop antennas, separately controlled by two transmitters. Compared to the situation in which one antenna is used, this configuration requires double transmission power for the same field strength.

The object of the invention is to overcome this drawback and generally to provide a simply yet reliably operating detection system, in particular suitable for shoplifting detection.

To this end, according to the invention, an electromagnetic detection system of the type described hereinabove is characterized in that one loop antenna coil of the antenna configuration is part of a series resonance circuit, and that the other loop antenna coil is part of a parallel resonance circuit, the series resonance and parallel resonance circuits having the same resonance frequency and being interconnected to form a combined antenna network connected to the source circuit, and the series resonance and parallel resonance circuits being dimensioned such that the frequency-dependent parts of the impedances substantially compensate each other, so that the combined antenna network has a substantially frequency-independent impedance.

The invention will be further explained hereinafter, with reference to the accompanying drawings, in which:

Fig. 1 schematically illustrates an eight-shaped antenna with the detection field formed by it;

Fig. 2 schematically shows an example of a parallel resonance circuit;

Fig. 3 schematically shows the impedance variation of the circuit of Fig. 1 as a function of the frequency;

Fig. 4 schematically shows an example of a series resonance circuit;

Fig. 5 schematically shows the impedance variation of the circuit of Fig. 4 as a function of the frequency;

Fig. 6 schematically shows an example of a combined circuit having a parallel resonance circuit and a series resonance circuit;

Fig. 7 schematically shows the voltage variation over the circuit of Fig. 6 as a function of the frequency;

Fig. 8 schematically shows a first exemplary embodiment of an antenna configuration for use in a system according to the invention; and

Fig. 9 schematically shows a second exemplary embodiment of an antenna configuration for use in a system according to the invention.

Fig. 1 shows an eight-shaped antenna 1 which, as is conventional in shoplifting systems, is positioned substantially vertically to form a detection field M in a detection zone typically located near an exit. Detection labels that may still be attached to articles carried along by customers, also referred to as responders or transponders, can be detected in the detection zone. Such responders comprise a resonance circuit tuned to the frequency of the detection field, whose coil is at least partly designed as a loop antenna. In Fig. 1, two responders are schematically indicated by 2 and 3.

Typically, antennas are controlled as a parallel circuit (see Fig. 2) having a resonance frequency  $f_0$ , determined by the (antenna) coil L1, the capacitor C1 and a Q-factor determined by the resistor R and the L1/C1 ratio. The Q-factor increases the antenna current relatively to the transmitter current, but has as a negative consequence a strongly varying impedance Z1 of the parallel circuit, as shown in Fig. 3. At the frequencies f1 and f2, the magnitude of the impedance has decreased by 30%. The distance between f1 and f2 decreases at an increasing Q-factor according to:

$$f_2 - f_1 = f_0/Q$$

An alternative is formed by the series circuit shown in Fig. 4, comprising a resistor R, a capacitor C2 and a coil L2. This series circuit has an impedance variation Z2, shown in Fig. 5, whose variation is opposite to that of the parallel circuit; at f1 and f2 the magnitude of the impedance has increased by 40% relatively to the impedance at the resonance frequency  $f_0$ . In both cases the Q-factor determines the ratio of the magnetic energy in the coil, i.e. the field strength, and the transmitter power available; in other words, the efficiency.

A frequency-dependent impedance is a problem in particular if the transmitter is situated at some distance from the antenna, so that a transmission line (for instance a coaxial cable) must be placed between transmitter and antenna. An intermediate length of transmission line causes the impedance "seen" by the transmitter (source) to be even more frequency-dependent. The standing waves that are thus formed in the cable result in interfering resonances.

According to the invention, by placing the two types of networks of Figs 2 and 4 in series with the same quality factor Q and resonance frequency and with the same, for instance common, load resistance, a constant impedance can be realized. A schematic example is shown in Fig. 6. In the circuit shown in Fig. 6, the parallel circuit is formed by L1 and C1, and the series circuit by L2 and C2.

In this example,

it applies that:  $L1/C1 = R^2/Q^2$   
 and  $L2/C2 = R^2 \times Q^2 = L1/C1 \times Q^4$   
 with  $L1 \times C1 = L2 \times C2 = (1/2\pi f_0)^2$

Here, the voltage variation over the parallel circuit V1 is determined by the impedance variation of the circuit with the frequency as if the circuit is fed by a current source. Hence, the voltage variation is independent of the transmitter impedance. However, the maximum voltage over the circuit V1 at the resonance frequency is the same as in the case where the series circuit is absent. The voltage over the series circuit V2 has an opposite variation, so that the total voltage over the series-connected networks V1 and V2 is constant, as is shown in Fig. 7. To the current in the series circuit, about the same applies as to the voltage over the parallel circuit.

From the network comparisons it further follows that:

- the currents in the two coils have more or less the same frequency variation;
- the average energy contents  $I^2 \times L$  are equal;
- at all frequencies, the phase difference between the two coil currents is 90 degrees.

An antenna network thus combined forms a frequency-independent impedance for the transmitter.

To remove dead spots as a result of a wrong field orientation, such as may be responsible for the trouser pocket effect, magnetic rotary fields can be used. An example thereof is given in EP-A-0186483 by Senelco Limited.

In essence, a magnetic rotary field is generated by two magnetic fields, which:

1. are spatially perpendicular to each other, and
2. differ in phase relatively to each other by 90 degrees.

According to EP-A-0186483, a rotary field is generated with two antennas, separately controlled by two transmitters which, in turn, are controlled from one signal via a 90 degrees phase-shifting network.

Alternatively, one transmitter may be used, followed by a power splitter and a phase-shifting network. In both cases, the double transmission power is required to realize the same field strength by means of the two antennas as is realized by means of one antenna.

In the case of a receiver antenna, the detection sensitivity for a field in one of the two orientations will be halved by the power splitter relatively to the sensitivity with one antenna.

An alternative to a rotary field is alternately energizing the two antennas. This eventually yields the same reduction in field strength or sensitivity as the above-mentioned method. The reason that magnetic rotary fields are not yet widely applied in shoplifting detection systems is the complexity of the equipment required for feeding the two antennas as in EP-A-0186483, and the reduction in field strength or sensitivity. The coil L2, provided in the impedance-compensation network shown in Fig. 6 and described hereinabove, produces a magnetic field, shifted in phase through 90 degrees relatively to the transmitting antenna coil L1. By positioning the coil L2 as an additional auxiliary antenna, as shown in Fig. 8, a magnetic rotary field is generated in a simple manner.

In the network described above and shown in Figs 6 and 8, the resonance of two antenna coils is damped by one resistor. Here, both antennas are coupled to the transmitter or receiver to the same extent as in the case of one antenna, unlike the conventional method in which the coupling is halved in both directions. In the circuit of Fig. 6, the power available is utilized twice, as it were.

Thus, the convention combines the use of an impedance conversion network and the loss-less generation of a magnetic rotary field.

Fig. 8 shows an example of an embodiment of an antenna configuration according to the invention. A conventional, shielded eight-shaped antenna 4 is incorporated as a coil L1 in a parallel circuit and forms the main antenna. A small zero-shaped antenna 5 at the centre of the eight-shaped antenna is incorporated as a coil L2 in a series circuit and forms the auxiliary antenna.

The auxiliary antenna provides an additional horizontal field 6 at the centre. The horizontal field, together with the vertical field of the main antenna, approximately equally large, forms a rotary field, enabling detection of a label in all orientations.

Because at distances greater than its width, the field of a zero-shaped antenna reduces less quickly than that of an equally wide eight-shaped antenna, and because the pocket trouser effect only occurs at the centre, the auxiliary antenna, at a comparable field strength, can be smaller than the main antenna.

Fig. 8 further shows a shield 7, positioned behind the antenna configuration. In the shield 7 behind the auxiliary antenna, an opposed current is induced, strongly reducing the field strength at a great distance, so that at a distance of for instance 10 m, this current is not much greater than that of the main antenna. If the symmetry of the main antenna is disturbed by metal in the environment, or by a non-perpendicular arrangement, the far field of the main antenna will even be predominant.

In this configuration, the sensitivity to interfering fields from outside the system is therefore comparable to that of a shielded eight-shaped antenna, in spite of the zero-antenna used.

An alternative antenna configuration is a combination of two uniplanar eight-shaped antennas forming one mechanical whole. Fig. 9 shows an example. The connection points of the two coils L1 and L2 are indicated by P1, P2 and S1, S2 respectively.

The magnetic field lines of L1 and L2, indicated in Fig. 9 by 7 and 8 respectively, result in a rotary field, comprising, above the whole plane except at the centre, a component perpendicular to the plane, so that a detection label passing the antenna parallel to this plane will always be detected.

For detection labels passing parallel to the antenna plane, symmetric eight-shaped antennas have a dead spot in the form of a plane, perpendicular to the antenna plane, intersecting the antenna plane at the transverse joint. A uniplanar system of two independent eight-shaped detection antennas has a dead spot being on the line where the two separate dead spots intersect. This intersecting line is perpendicular to the antenna plane and intersects the antenna plane at the junction of the two transverse joints.

If the transverse joints of the two antennas intersect perpendicularly, the two coils are inductively uncoupled and can be controlled by the circuit of Fig. 6 via two transformer couplings k1, k2 as parallel and series circuits. Accordingly, the magnetic fields of the two eight-shaped antennas are 90 degrees out of phase, so that they, as it were, function independently as detection antenna. A dead spot in the form of a line ensures that a detection label which passes parallel to the antenna plane can always be detected.

Consequently, this antenna configuration combines the advantages of a zero-shaped antenna and those of an eight-shaped antenna: 1) no dead spots in which a label oriented parallel to the antenna plane can pass without being detected, and 2) a small field strength at a great distance relatively to a strong field at a short distance.

It is observed that after the foregoing, various modifications will readily occur to a person skilled in the art. For instance, the resonance circuits may comprise several coils or capacitors. Also, an antenna configuration as described can, for instance, be used in a horizontal position or another orientation. Optionally, the antenna coils can be coupled to a circuit according to Fig. 6 via a transformer. Such modifications are considered to fall within the scope of the invention.

## Claims

1. An electromagnetic detection system comprising at least one source circuit and at least one source circuit-controlled antenna configuration, which comprises two loop antenna coils, substantially located in one plane or in closely spaced parallel planes, for generating a detection field in a detection zone, and a plurality of responders, provided with a loop antenna coil, detectable in the detection zone by means of the detection field, characterized in that one loop antenna coil of the antenna configuration is part of a series resonance circuit, and that the other loop antenna coil is part of a parallel resonance circuit, the series and parallel resonance circuits having the same resonance frequency and being interconnected to form a combined antenna network connected to the source circuit, and the series and parallel resonance circuits being dimensioned such that the frequency-dependent parts of the impedances substantially compensate each other, so that the combined antenna network has a substantially frequency-independent impedance.
2. An electromagnetic detection system according to claim 1, characterized in that the series-resonance circuit and the parallel resonance circuit have the same quality factor Q.
3. An electromagnetic detection system according to claim 1 or 2, characterized in that the series resonance circuit and the parallel resonance circuit have the same load resistance.
4. An electromagnetic detection system according to any one of the preceding claims, characterized in that

the antenna configuration comprises an eight-shaped main antenna and a substantially smaller, zero-shaped auxiliary antenna, positioned at the centre of or at a short distance from the plane of the main antenna, which auxiliary antenna, during operation, supplements the magnetic field, oriented parallel to said plane of the main antenna, at the centre of the main antenna to form a magnetic rotary field.

- 5 5. A magnetic detection system according to any one of claims 1-3, characterized in that the antenna configuration comprises two eight-shaped antennas, substantially positioned in one plane, shifted through 90° in the plane relatively to each other, one eight-shaped antenna being coupled to the parallel resonance circuit and the other eight-shaped antenna being coupled to the series resonance circuit.
- 10 6. A magnetic detection device according to claim 5, characterized in that the two eight-shaped antennas form one mechanical whole, but are magnetically uncoupled by the use of a common loop having two sets of symmetrically positioned transverse branches, extending transversely to each other, provided with terminals, the terminals of one transverse branch being coupled via a first transformer coupling to the parallel resonance circuit and the terminals of the second transverse branch being coupled via a second transformer coupling to the series resonance circuit.
- 15 7. An electromagnetic detection system according to any one of the preceding claims, characterized in that the source circuit is spaced from the antenna coils and connected thereto via a relatively long cable.
- 20 8. An antenna device for use in an electromagnetic detection system, characterized in that the antenna device comprises two loop antenna coils, substantially positioned in one plane or in closely spaced planes, and that one antenna coil is part of a series resonance circuit and the other antenna coil is part of a parallel resonance circuit, the series and parallel resonance circuits having the same resonance frequency and being interconnected to form a combined antenna network, the series and parallel resonance circuits being dimensioned such that the combined antenna network has a substantially frequency-independent impedance.
- 25 9. An antenna device according to claim 8, characterized in that the series resonance circuit and the parallel resonance circuit have the same quality factor Q.
- 30 10. An antenna device according to claim 8 or 9, characterized in that the series resonance circuit and the parallel resonance circuit have the same load resistance.
- 35 11. An antenna device according to any one of claims 8-10, characterized in that the antenna configuration comprises an eight-shaped main antenna and a substantially smaller, zero-shaped auxiliary antenna, positioned at the centre of or at a short distance from the plane of the main antenna, which auxiliary antenna, during operation, supplements the magnetic field, oriented parallel to said plane of the main antenna, at the centre of the main antenna to form a magnetic rotary field.
- 40 12. An antenna device according to any one of claims 8-10, characterized in that the antenna configuration comprises two eight-shaped antennas, substantially positioned in one plane, shifted through 90° in the plane relatively to each other, one eight-shaped antenna being coupled to the parallel resonance circuit and the other eight-shaped antenna being coupled to the series resonance circuit.
- 45 13. An antenna device according to claim 12, characterized in that the two eight-shaped antennas form one mechanical whole, but are magnetically uncoupled by the use of a common loop having two sets of symmetrically positioned transverse branches, extending transversely to each other, provided with terminals, the terminals of one transverse branch being coupled via a first transformer coupling to the parallel resonance circuit and the terminals of the second transverse branch being coupled via a second transformer coupling to the series resonance circuit.
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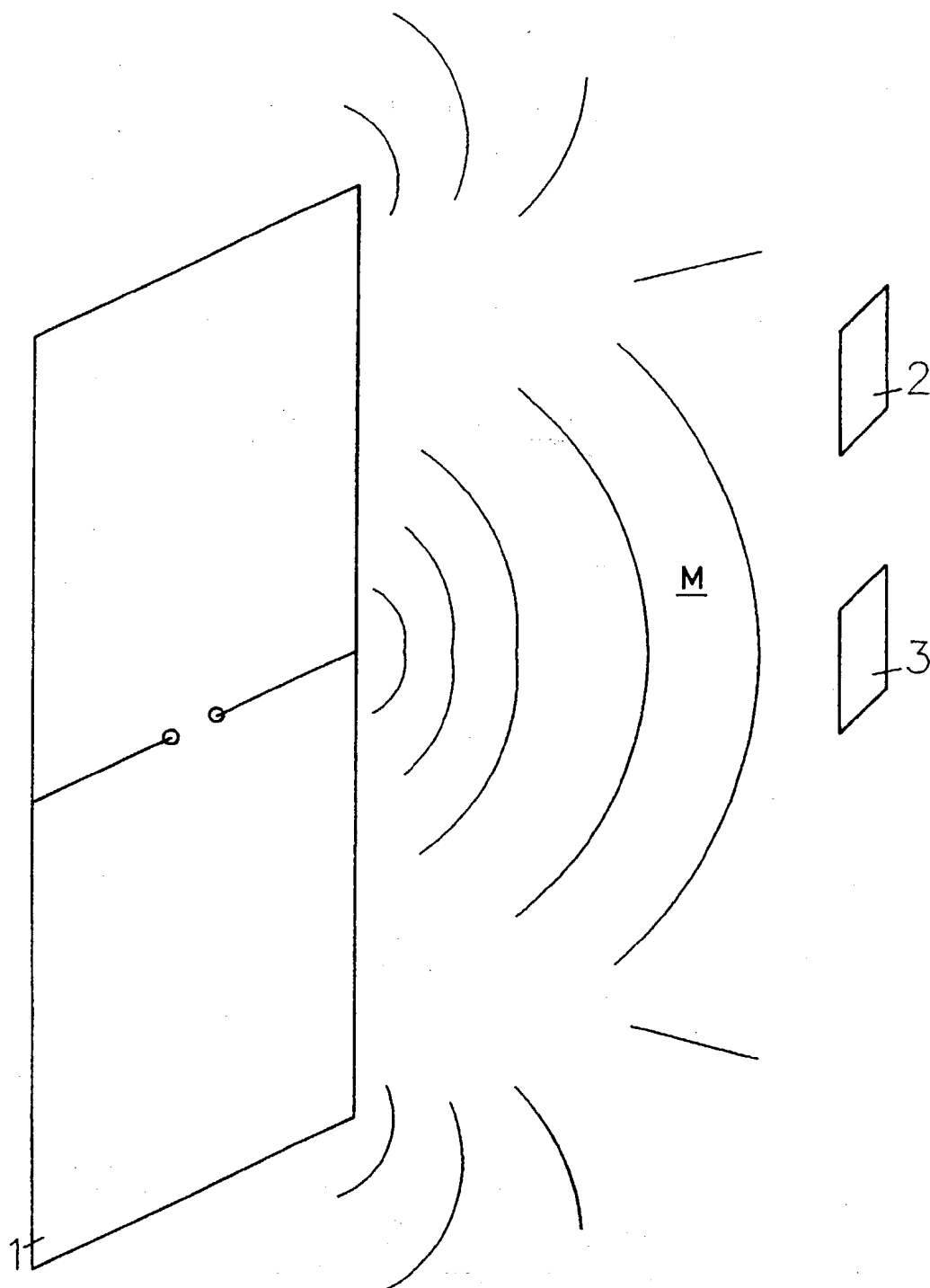


FIG. 1



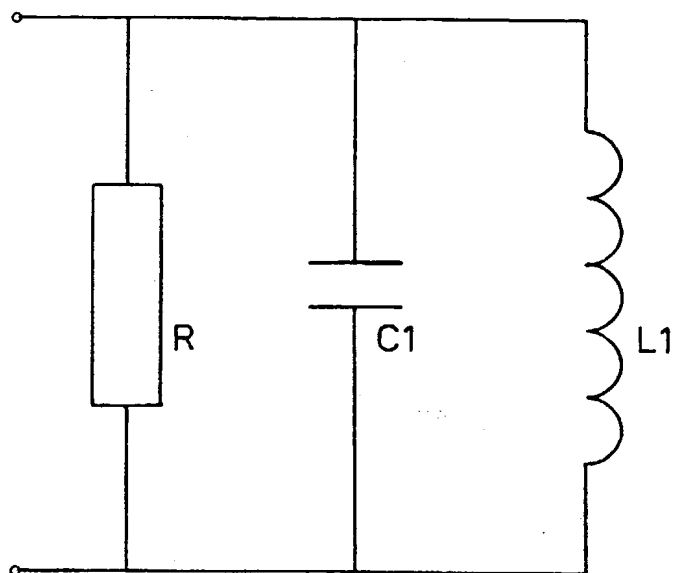


FIG. 2

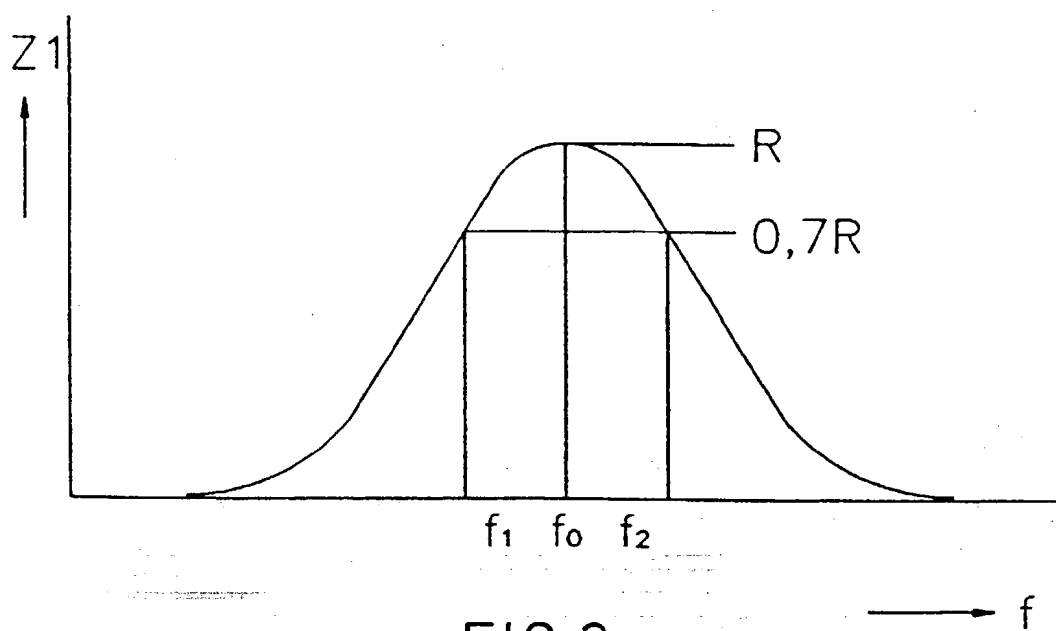


FIG. 3

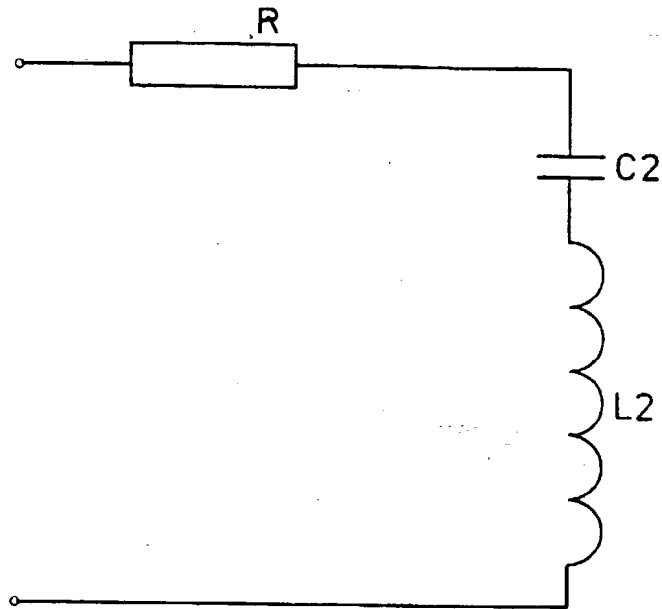


FIG. 4

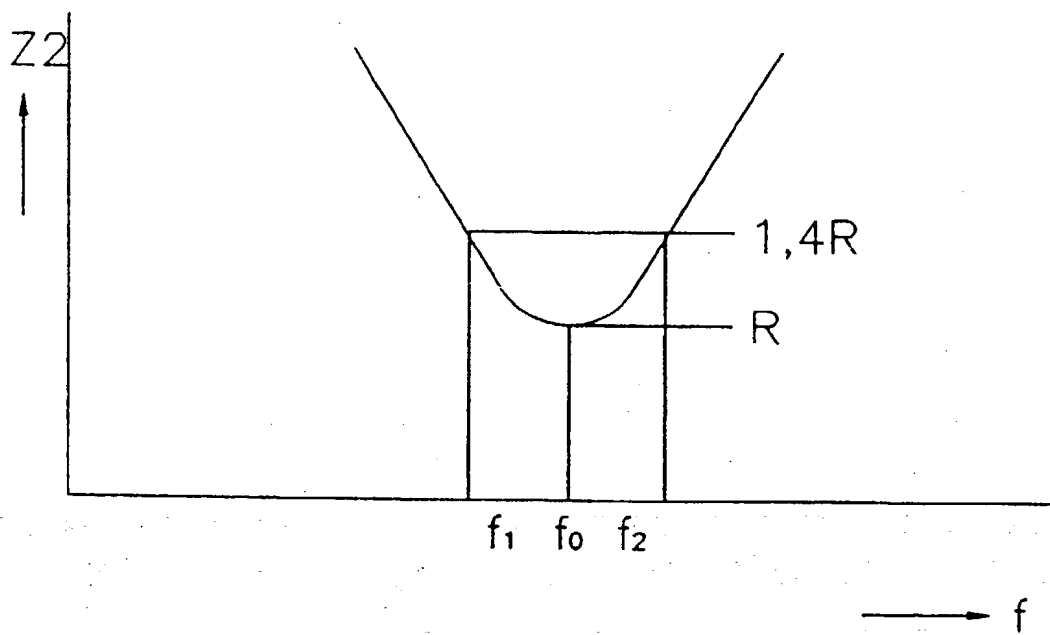


FIG. 5

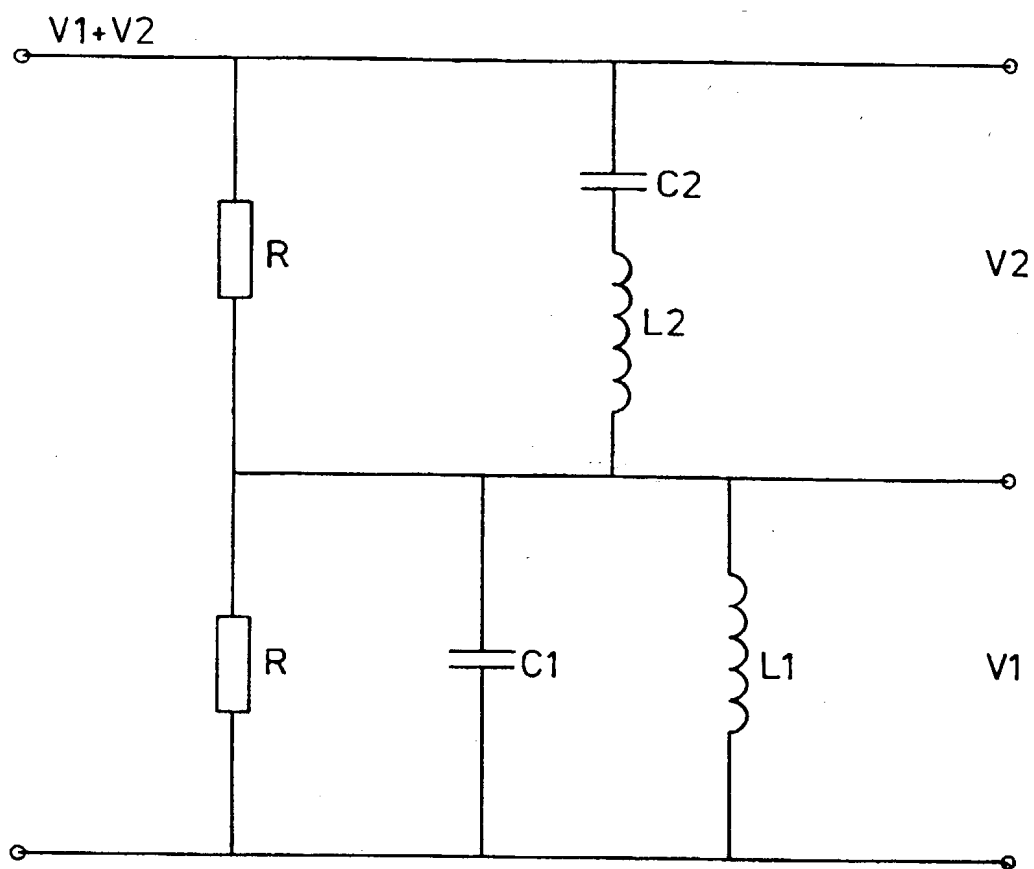


FIG. 6

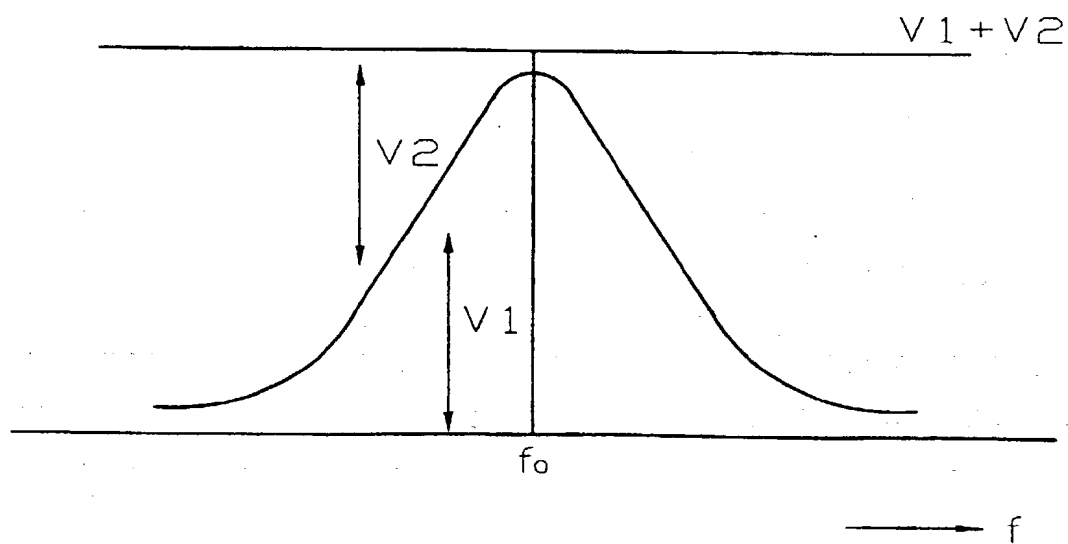


FIG. 7

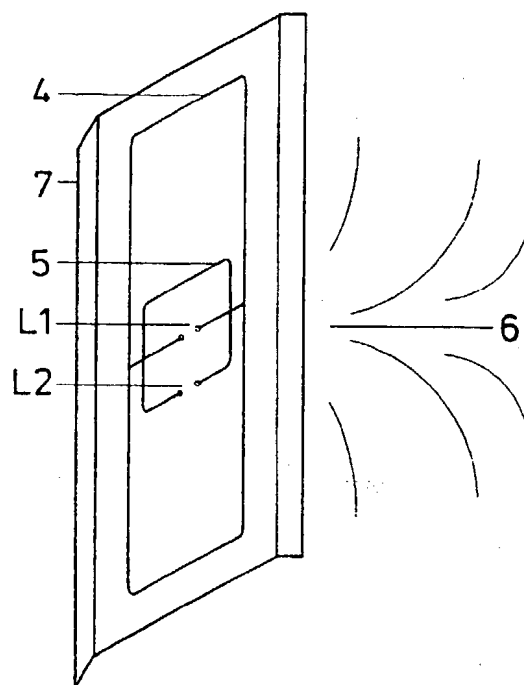


FIG. 8

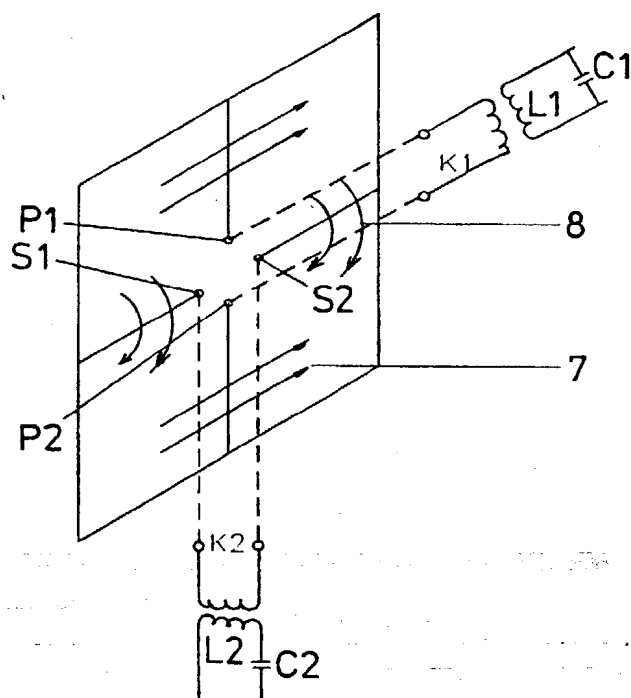


FIG. 9



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# EUROPEAN SEARCH REPORT

Application Number

EP 93 20 2073

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
D,A	EP-A-0 186 483 (SENELCO, LTD.) * figures 1-3 * * page 3, line 10 - line 33 * ---	1,4,8,11	G08B13/24
A	EP-A-0 478 092 (N.V.NEDERLANDSCHE APP., NEDAP) * figure 5 * * column 5, line 25 - line 43 * ---	1,5,6,8,12,13	
A	DE-A-3 045 703 (ELAN SCHALTELEMENTE, K.M. GMBH) * figure 5 * * page 4, line 26 - page 5, line 7 * -----	1,6,8,13	
			TECHNICAL FIELDS SEARCHED (Int. CL.5)
			G08B G01S
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 18 OCTOBER 1993	Examiner WEISS P.
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